

**THE COMMERCIALIZATION
OF BIOTECHNOLOGY
IN ALBERTA**

November 1995

TABLE OF CONTENTS

FOREWORD	i
EXECUTIVE SUMMARY	1
The Issues	1
List of Recommendations	2
Scientific Infrastructure	2
Human Resources	3
Technology Transfer	4
Intellectual Property Protection	5
Accessing Capital	5
Public Awareness	6
Regulations	6
Partnering	7
Strong Voice for Industry	7
INTRODUCTION	8
Biotechnology: A Definition	8
The Industry	9
Biotechnology companies by Geographic Area	9
Biotechnology Companies by Industry Sector	10
APPLICATION OF BIOTECHNOLOGY	11
Biological and Biopharmaceutical Products	11
Agriculture and Food	12
Animal Agriculture	13
Plant Agriculture	13
Aquaculture	15
Environmental Applications	15
Soil and Water Remediation	15
Cleaning and Sanitation	15
Waste Disposal	16
Forestry	16
Plant Development	16
Pulp and Paper	16
Mining	16
Fossil Fuels	17
ISSUES SPECIFIC TO THE ALBERTA BIOTECHNOLOGY INDUSTRY	17

Infrastructure for Scientific Research	17
Human Resources	19
Scientific Personnel	19
Management	19
Issues of Technology Transfer	20
Research and Development	20
Lack of Incentive for Researchers	20
Technology Transfer and Diffusion to Industry	20
Accessing Capital	21
Public Awareness	22
Regulations	23
Intellectual Property Protection	23
Partnering	24
VISION FOR THE FUTURE	25
The Opportunities	25
Jobs	25
Economic Growth.....	25
Export Potential.....	25
APPENDIX 1	27
Members of the Biotechnology Committee:	27
April 19, 1995 Focus Group Meeting:	27
April 27, 1995 Focus Group Meeting:	27
APPENDIX II	28
Interviews Conducted by the Committee:	28
Institutions, Companies and Individuals Visited:.....	28
REFERENCES	29

FOREWORD

On September 15, 1994, Premier Ralph Klein announced the establishment of the Alberta Science and Research Authority (ASRA) and appointed the Honourable Dianne Mirosh, MLA (Calgary-Glenmore) as Minister. The Authority is responsible for the establishment of short and long-term goals for the Government's science, research and technology development activities in Alberta. These goals provide a basis for a strategic plan to address priority needs, capitalize on emerging opportunities, integrate complementary programs, agencies, and other initiatives, and maximize the overall effectiveness of research funding.

The Authority is led by a Board of Management reporting directly to the Minister. The Board of Management is chaired by Dr. R. Church. Sixteen others with expertise in science and research, development and related business fields serve on the senior science and research body. Working with the Alberta Economic Development Authority, the ASRA will provide expertise and direction to a broad range of economic policies to support the commercialization of new technologies and processes currently being developed through Alberta's research-based activities. Biotechnology has been identified as one of the technology-based fields.

A committee on the "Commercialization of Biotechnology in Alberta" was formed in December 1994 to review biotechnology research and industrial activities and organizations in Alberta and bring forth recommendations that could assist in the successful commercialization of biotechnology. Members of the Biotechnology Committee included Board of Management members Dr. W. Cochrane, Chairman; Dr. R. Collins-Nakai; Dr. R. Rennie; and Mr. I. Hamilton. Dr. A. Sailer was engaged as a support staff member to assist the committee. Meetings were held with individuals from academe, business and government laboratories to identify issues and concerns (Appendix II). Reports and documents related to commercializing biotechnology were reviewed.

A draft document was prepared and two focused group meetings with individuals from various sectors involved in biotechnology (Appendix I) gathered to review the document. This gave representatives the opportunity to provide constructive criticism of the document as well as suggestions and further recommendations.

The issues and recommendations outlined in this report not only target the biotechnology industry but are equally applicable to other advanced technology areas. By understanding the interrelationships and issues common to industries in science, research and technology development in Alberta, we can begin to provide a basis for a strategic plan to address success factors crucial to the commercialization of new technologies and processes.

EXECUTIVE SUMMARY

The Biotechnology Committee has reviewed the mandate of the Minister Responsible for Science and Research and, within that context, this document emphasizes the role of biotechnology in achieving goals outlined by the Premier.

Alberta universities and government laboratories continue to demonstrate strength in biotechnology research. A strong science and research infrastructure is required to attract highly qualified scientists to our province and develop a thriving biotechnology sector.

The biotechnology industry in Alberta encompasses a diverse group of companies that range in size, technologies employed, and markets served. Their mission is to use biological processes to develop products for human health care, agriculture productivity, animal health, food safety and nutrition, and chemical and environmental improvement.

The application of biotechnology to many industrial sectors will contribute greatly not only to economic growth but also to an enhanced quality of life for all Albertans, Canadians and citizens of other countries. The use of biotechnological techniques can result in enhanced food sources, an improved environment, and new drugs and vaccines of greater quality and lower cost, all for the benefit of society.

Nine issues specific to the Alberta biotechnology industry have been identified. While acknowledging the importance of all nine to the industry, some issues play a more significant role in certain sectors and in different stages of product development and commercialization.

The Issues

1. **Infrastructure for scientific research:** Funding to support infrastructure maintenance and upgrading for university research must be maintained. Failure to provide adequate support for facilities, equipment and support staff in Alberta may result in the loss of scientists to organizations outside the province.
2. **Human resources:** Given the intense international biotechnology activity, shortfalls of highly qualified people with research, production, management and legal expertise are expected.
3. **Issues of technology transfer:** Alberta requires an effective and consistent mechanism for the transfer of technology from research to industry.
4. **Intellectual property protection:** The protection of intellectual property is critical if investors are to be encouraged to provide financial support to the industry. Patenting is costly and complex and requires application to many countries. The present patent system is a cause of uncertainty and delay in translating scientific discoveries into

commercial successes. As a result, much of the patent work for Alberta biotechnology companies is done by U.S. attorneys.

5. **Accessing capital:** There is a lack of financing available in Alberta to support new businesses and the significant costs of taking technologies and new products through to market.
6. **Public awareness:** Public perception of the risks and benefits associated with specific applications of new biotechnologies is important to the overall success of the industry. Many people rely on the media for an accurate assessment of new technologies.
7. **Regulations:** Federal, provincial and municipal regulations are a critical determinant of the cost and time required to bring a new biotechnology product to market. Current delays and regulatory uncertainties are discouraging new research and investment, driving up the costs of innovation and undermining public confidence.
8. **Partnering:** New and maturing biotechnology companies can benefit through a partnering relationship through financial and human resource expertise, networking, production capability and distribution channels.
9. **Strong voice for industry:** Alberta companies involved in biotechnology require a strong, credible voice and a supporting infrastructure in order to play an advocacy role on such issues as intellectual property protection and regulatory requirements for the products and processes of biotechnology.

As a result of extensive study and consultation with stakeholders in this field, the Biotechnology Committee has identified needed changes in public policy. Implementation of these changes would greatly enhance the likelihood that Alberta will be in a competitive position to realize the economic potential of these technologies.

List of Recommendations

Scientific Infrastructure

It is recommended that:

1. the **Alberta Science and Research Authority (ASRA)** develop an **electronic base of information** for biotechnology research in our universities, government laboratories, and industry. The purpose would be to identify individuals, their location and their biotechnology research activities.
2. the **Minister Responsible for Science and Research** promote continued financial support from both federal and provincial governments for university science facilities and people involved in biotechnology research.

3. the **Alberta Science and Research Authority** establish a **Biotechnology Committee**. This mandate of this committee is to promote the development of a strong biotechnology industry in Alberta. As part of its mandate, the Biotechnology Committee would **monitor** the level of financial support for basic science research at our university and government laboratories, and report **annually** to the **ASRA Board**.

Human Resources

Scientific:

It is recommended that:

4. the **Alberta Science and Research Authority** strongly support the **Department of Education's** activities to increase science programs at elementary and secondary schools within the province and monitor the progress in this area.
5. the **Alberta Science and Research Authority in conjunction with Alberta Advanced Education and Career Development** encourage the **Boards of Governors** and **senior administration** at Alberta institutions to **support** undergraduate and graduate science programs, particularly those in the life sciences.

Management:

To address the **immediate** shortage of skilled management personnel it is recommended that:

6. the **Alberta** government should encourage the **Federal Government** to support recruitment of skilled managers from outside the country to meet the management needs of biotechnology companies. Representatives from biotechnology companies should be familiar with local government immigration officials and communicate their management needs to assist in expediting immigration of much needed management expertise.
7. the **Alberta Science and Research Authority** seek advice and involvement from the **Alberta Economic Development Authority** and the **Alberta Chamber of Commerce** in establishing a **mentoring program**. This would provide managers of new biotechnology companies, through secondment of middle management from larger companies, an opportunity to learn by one-on-one interaction. The initial emphasis should be on financial and marketing management personnel. Federal **human resource funding programs** could be a source of financial support for such a mentoring process.
8. the **Alberta Science and Research Authority** in association with the **Alberta Economic Development Authority** recommend to the **Government of Alberta** that the Banff School of Advanced Management, the Faculties of Management at the University of Calgary, University of Alberta, Athabasca University and the University

of Lethbridge develop **executive management programs** emphasizing skills of management for emerging small and medium sized science-related companies.

To address future needs it is recommended that:

9. the **Alberta Science and Research Authority**, recommend the development of programs at Alberta universities combining life sciences with management programs (**e.g. combined MBA/Life Science degree**).

Technical:

It is recommended that:

10. the **Alberta Science and Research Authority Biotechnology Committee** establish a **Technical Advisory Sub-committee** comprised of representatives from the **Alberta Science and Research Authority, Alberta Research Council, industry representatives, the technical institutions and community colleges** to explore the need for (and development of) programs for biotechnology technicians. This would address the potential shortage of qualified technicians in the province and could align education programs with future industry needs.

Legal:

To address immediate needs it is recommended that:

11. the **Alberta Science and Research Authority** encourage the **Alberta Bar Association** to promote greater communication and collaboration between members of the legal profession and representatives from the biotechnology industry.

To address future needs it is recommended:

12. the **Alberta Science and Research Authority**, with the **Department of Advanced Education and Career Development**, approach the province's two **law schools** and the **Alberta Bar Association** to encourage greater knowledge and experience in patenting and intellectual property protection specific to the biotechnology industry, both on a national and international basis.

Technology Transfer

It is recommended that:

13. the **Governemnt of Alberta through the Ministry for Science and Research** award **\$350,000 per year per university** to technology transfer offices for a period of **five years**. This would be in addition to the funds presently allocated by university funding.
14. the **Alberta Science and Research Authority** encourage the **Department of Economic Development and Tourism** in cooperation with the **Department of Advanced Education and Career Development** to establish a **Joint Technology**

Transfer Committee with representatives from **University Technologies International Inc.** in Calgary and the **University of Alberta Industry Liaison Office in Edmonton, the Alberta Research Council, and industry**, to increase collaboration and coordination of technology transfer offices. The objectives of the committee would be to minimize duplication and allow for combined local and international marketing efforts. This same committee could **coordinate** technology transfer from other **research facilities** in the province.

15. the **Department of Alberta Economic Development and Tourism** establish a **“Marketing Advisory Group”** to assist technology transfer offices and Biotechnology companies to market internationally their discoveries and products. Such a committee would work with provincial representatives, along with the **Federal Department of Foreign Affairs and Industry Canada**.

Intellectual Property Protection

It is recommended that:

16. the **Ministry for Science and Research** should provide an intellectual property advisory role to the technology transfer offices. In addition to the \$350,000 per year per technology transfer office, **\$100,000 per year per office** would be allocated for the purpose of funding the high cost of intellectual property protection of innovative technologies.
17. the **faculties of law** in the province should be asked to host a **conference** to determine the needs of the biotechnology industry. This would allow issues to be identified to determine what patent knowledge and skills are required to meet the needs of the Alberta biotechnology industry. Such a conference should include representatives from the **law faculties, industry and patent authorities**.

Accessing Capital

To enhance investment and minimize risk, it is recommended that the Government of Alberta:

18. implement a **revised tax structure** to encourage individuals and business to invest in biotechnology in the Province. Highlights of such a tax structure should include:
 - a) a **capital gains tax** exemption whereby the tax paid on an investment in science and research be reduced, depending on the number of years the investment is held, and
 - b) a **forgivable tax** for the purpose of attracting and retaining qualified **people** and biotechnology **companies** to our province.
19. a review of provincial tax treatment of R&D expenditures.

20. establish a **merchant bank** in partnership with existing financial institutions for the purpose of providing funding to start-up biotechnology companies.
21. review policies with respect to **labor sponsored venture capital pools**, such as the Canadian Medical Discoveries Fund, for the purpose of investment in biotechnology companies. The **Government of Alberta** should establish and encourage investment in such funds **immediately** since the possibility exists that federal legislation may eliminate this vehicle for funding.

It is also recommended that:

22. the **Alberta Science and Research Authority**, together with the **Alberta Economic Development Authority**, should host an **annual biotechnology investment conference** to attract financial and investment organizations for the purpose of targeting investment opportunities in Alberta biotechnology companies.

Public Awareness

It is recommended that:

23. the **Alberta Science and Research Authority** establish a **Public Awareness and Education Committee** to create an increased knowledge, interest and support for science by Alberta's citizens. Additional members from the media, educational community and public would be invited.

Regulations

Regulations in the province are presently undergoing a review. The goal should be to **reduce, simplify and standardize** regulations in the Province for biotechnology. It is therefore recommended that:

24. the **Alberta Science and Research Authority** establish a **Biotechnology Regulatory Review Committee** comprised of Government and non-government representatives working with the **Regulatory Task Group of the Alberta Economic Development Authority**. This would provide input on concerns as well as examine the impact of regulations, on a cost benefit basis. This would provide some insight to determine which regulations are impeding growth of the biotechnology industry.
25. the **Minister Responsible for Science and Research**, together with **ministerial colleagues in other provincial governments** and the **Premier of Alberta**, act as a voice to raise regulatory concerns, with the Federal Government, specific to the biotechnology industry.

Partnering

It is recommended that:

26. the **Alberta Economic Development and Tourism, Technology Development Branch** continue to support **biopharmaceutical conferences**, but broaden the scope to attract partners in other industry sectors involved with biotechnology, especially **agriculture and environment**.
27. the **Department of Advanced Education and Career Development** provide information and training assistance to companies seeking a partnering relationship by establishing an educational program at one of our academic institutions. Such a program would emphasize skill development in the areas of finance, negotiation, marketing, and international business.
28. the **Government of Alberta through Alberta Economic Development and Tourism** provide **funds** to promote and support Alberta Biotechnology company representation at national and international biotechnology and investment conferences for the purpose of attracting business partnerships and capital.

Strong Voice for Industry

It is recommended that:

29. the **Biotechnology Committee** of the Alberta Science and Research Authority would initially act as a voice for the industry, but within six months would provide recommendations to the Alberta Science and Research Authority as to the organizational structure of such a voice for Alberta. In Canada, federal and provincial associations (e.g. NBAC, IBAC, CIB, and B.C.B.A.¹) do exist, but the Alberta biotechnology industry is fragmented. Consideration should be given to establish a **provincial biotechnology association** to represent all sectors of the industry.
30. the **Minister Responsible for Science and Research** encourage regular communication between representatives from the **biotechnology industry** and the **Government of Alberta foreign trade offices, Canadian embassies** and the **Federal Department of Foreign Affairs and International Trade**.
31. the **Alberta Science and Research Authority** establish a central base of information to include Alberta's academic scientists engaged in biotechnology R&D, the Alberta Research Council and biotechnology companies based in Alberta. Information and representatives from the various biotechnology sectors could be called upon to assist in provincial, national and international marketing efforts.

¹ National Biotechnology Advisory Council, Industrial Biotechnology Association of Canada, Canadian Institute of Biotechnology, British Columbia Biotechnology Alliance

Introduction

In an address delivered to the Legislative Assembly of Alberta in January 1994, Premier Ralph Klein stated:

It shall be the policy of this government that science, technology, and industrial innovation are critical components of economic growth, and form an integral part of our economy and culture.

To implement such a policy, Premier Klein established the Alberta Science and Research Authority (ASRA) headed by the Minister Responsible for Science and Research, Honourable Dianne Mirosh, MLA (Calgary-Glenmore). The Authority is responsible for the establishment of short-term and long-term goals for the Government's science, research and technology development activities in Alberta. Working with the Alberta Economic Development Authority, the Alberta Science and Research Authority proposes to maximize strategic opportunities in a number of technology-based fields, including *biotechnology*.

The Authority identified a subcommittee to review biotechnology research and industrial activities and organizations in Alberta, and bring forth recommendations that could assist in the successful commercialization of biotechnology. This subcommittee has reviewed the mandate of the Minister Responsible for Science and Research and, within that context, this document emphasizes the role of biotechnology in achieving goals outlined by the Premier.

Biotechnology impacts the competitive nature of all industry sectors. While these technologies offer a definite and major potential for competitive advantage, their industrialization is still emerging. Not only will biotechnologies create new products, they will also radically transform processes, in particular the efficient utilization of natural resources and the preservation of the environment. Biotechnology has the unique ability of providing products and processes for improving quality of life for all people in the world.

Government and business cannot ignore the strategic importance of biotechnology to a modern economy. Integrating policies and programs to ensure an environment conducive to the commercial exploitation of biotechnology can be key to Alberta's future economic strength.

Biotechnology: A Definition Biotechnology has been defined as the application of science and engineering to the direct or indirect use of living organisms, their parts or their products, in their natural or modified form to provide goods and services.

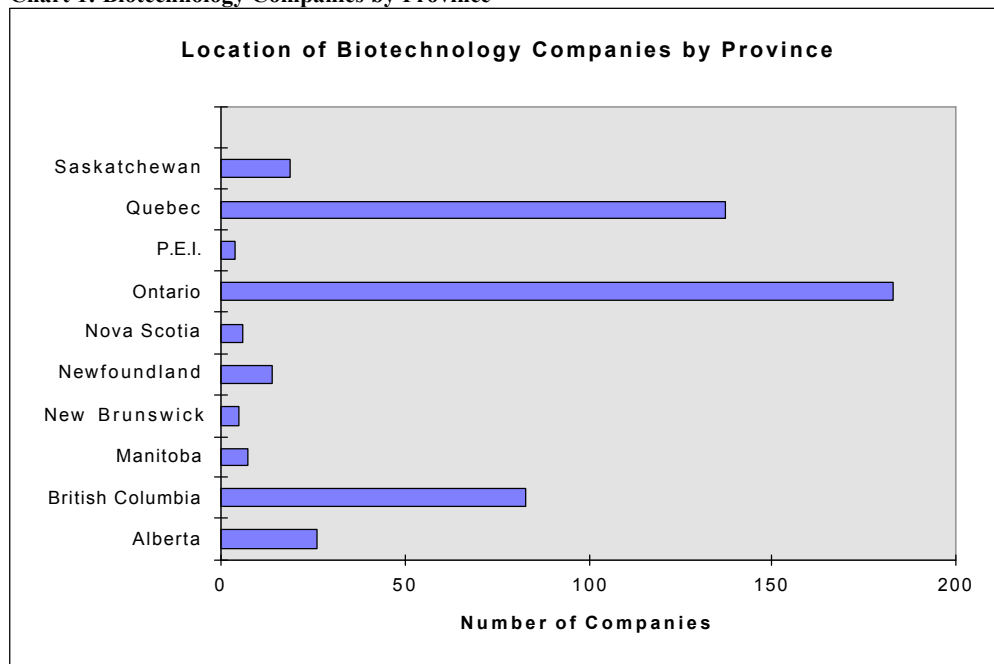
The Industry

The biotechnology industry encompasses a diverse group of companies that range in size, technologies employed, and markets served. Their mission is to use biological processes to develop products for human health care, agriculture productivity, animal health, food safety and nutrition, and chemical and environmental improvement. Also included are suppliers of technology based research products and equipment to biotechnology companies.

Biotechnology companies by Geographic Area

The 1994/5 Canadian Biotechnology Company Directory identifies some 651 companies and groups in Canada active in biotechnology. Of these, 506 are biotechnology companies or groups and 145 are companies or groups providing services to the biotechnology industry. This represents a 12% increase in the number of biotechnology companies in the country in the past year. **The directory acknowledges that the listings still do not account for the total number of such groups in Canada.** The four predominant geographic regions for biotechnology companies are Ontario (183 companies, 38%), Quebec (137, 28%), British Columbia (83, 17%) and Alberta (26, 5.4%).

Chart 1: Biotechnology Companies by Province



Biotechnology Companies by Industry Sector

In Canada, the three largest industrial sectors are health care, environment and agriculture; followed by engineering, forestry, and food and beverage. Alberta has a greater concentration of biotechnology companies in health care, environment and agriculture, with less representation in other industry sectors (refer to Chart 2 and 3).

Chart 2: Biotechnology Companies by Industry Sector (Canada 1994)

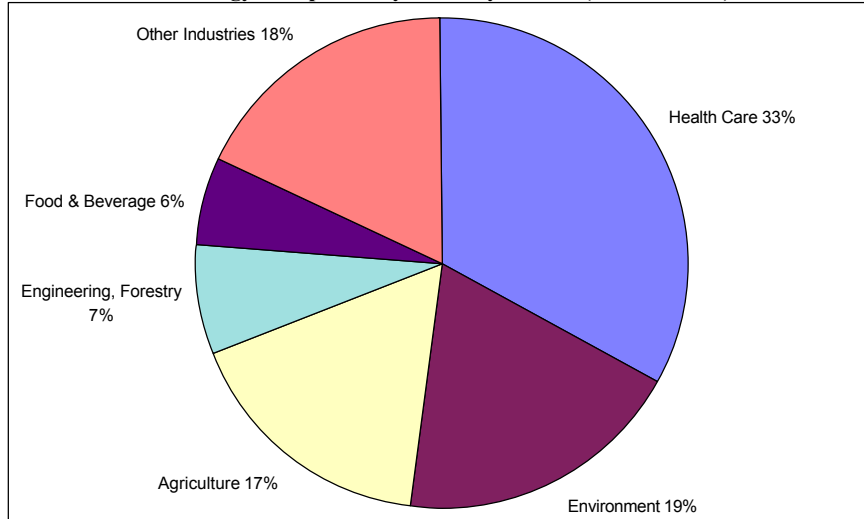
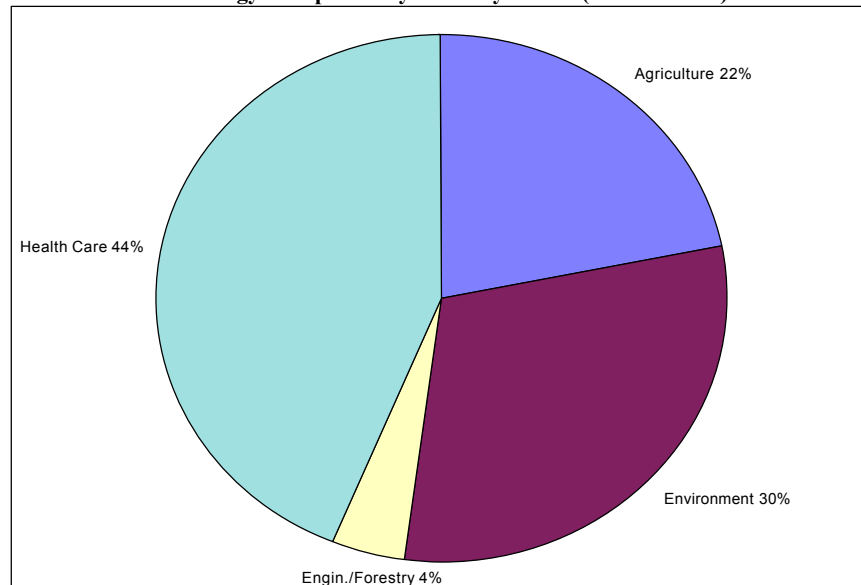


Chart 3: Biotechnology Companies by Industry Sector (Alberta 1994)



APPLICATION OF BIOTECHNOLOGY

Biotechnology has the ability to transform traditional industries as well as create new ones. The products and processes developed through biotechnology have commercial applications in many industry sectors. The enhancement to goods and services in all sectors is capable of improving quality of life. Alberta has on-going research and increasing numbers of companies involved in all applications of biotechnology.

Biological and Biopharmaceutical Products

Among the most intriguing areas of research using biotechnology are those pertaining to the nervous, immune, and endocrine systems, cancer research and vaccines for infectious disease. As research in these areas yields insight into mechanisms of disease and healthy body function, basic questions about the organization and function of the brain, the nature of behavior, and the regulation of body functions may be answered. New discoveries in these areas may generate possibilities for pharmaceutical products.

Canada does not have a strong international presence in conventional pharmaceuticals or in human biopharmaceuticals. Because of the attractive returns on investment from the successful application of biotechnology to the human biopharmaceutical sector, it is believed that emphasis in investment and research in this sector will continue to outpace other sectors.

Alberta has demonstrated strength in the international biomedical sector, principally through activities of university scientists and support from the Alberta Heritage Foundation for Medical Research. Maintaining a basic research infrastructure and professional scientific base is an essential requirement. Government regulation and licensing of pharmaceuticals play a major part in the development and commercialization of new products. Product development through the clinical trial stage may take years and requires significant capital.

Alberta is undergoing necessary restructuring of the healthcare system to meet the financial challenges of today. The expertise amassed in our province, and the international network of advisors we have established, are available to the province at a time when they are needed most. The cooperation of many research, education, health, government, and community organizations has positioned the province to expect more frontier work in science and in health research.

From research at universities commercial applications are identified, and further developed in government or private laboratory facilities. The commercialization of innovations is providing the basis for many new companies and for licensing agreements with others. Alberta biopharmaceutical companies are at active product development stages in health care related to cancer, Alzheimer's disease, Parkinson's disease and other conditions.

Alberta is a province *pioneering innovation for the future*. Basic research at our universities has been on-going for decades. It is this scientific base that provides training and develops expertise which can then be taken to an applied field. Science and technology have been identified as key to our future economic strength, and the creation of wealth and jobs in our province. Technology and scientific equipment are changing rapidly. Much of this equipment is manufactured outside of Canada and costs continue to escalate, magnified by the weakened Canadian currency. Alberta's reputation in the scientific community and the living standards it provides, have attracted researchers to our universities.

Often, technology must be transferred from basic and applied research to facilities for further product development. An example of such facilities would be the **Alberta Research Council** laboratories. Their recent client list includes firms from Japan and the U.S. This "scale-up" facility is the next step in determining the viability of the research to a production scale necessary for the commercial application of the product. Alberta-based biopharmaceutical companies are fortunate to have such facilities in our province.

Manufacturing, the next step in product development, has highly regulated protocols governed by standards of current **Good Manufacturing Practice (cGMP)**. cGMP aims to ensure that products are reproducible and consistently manufactured. Quality assurance is achieved by preliminary testing of the product in animals and then in a small group of patients. If the product is safe, it is tested in large numbers of subjects to prove efficacy. At this latter stage, firms must produce their materials using the method they intend to employ for full-scale production, ideally in the same production plant they will use for this purpose. Such facilities are limited in Canada today.

Alberta has biopharmaceutical companies in various stages of product development. Young companies in early product development require funds for research, product development, and intellectual property protection. Medium-sized firms ready for commercial breakthrough and subsequent growth are hampered by clinical trial regulations and cash flow problems. The success of these medium-sized firms could further be hampered by the financing requirements of building appropriate production facilities.

Agriculture and Food

Agricultural benefits from biotechnology include: improved crop varieties, new and improved agri-food products, more effective livestock vaccines, new uses for conventional agricultural commodities, better diagnostics for food safety, new techniques for improvement in the value-added processing industry, improved biological pest control agents, and improved resource management practices.

A recent study by the **Alberta Agricultural Research Institute** of the economic return to Alberta's agri-food industry from a **\$7.24 million** investment in twenty projects (some

with biotechnology applications), estimated a direct gross economic return of **\$455.6 million**. This represents a sixty dollar return for every dollar invested. Because of the importance of the agriculture sector to the overall competitiveness of the economy, Canada cannot fall behind its major international trading partners in the development and commercialization of new crop varieties, improvements to animal husbandry products and advances in food technology. Ag-West Biotech Inc. in Saskatchewan estimates that sales of **ag-biotech products will grow 50% a year** to the end of the decade.

Animal Agriculture

Alberta is the leading producer of livestock in Canada. The meat processing industry also represents the largest portion of Alberta's agri-food industry. Alberta is researching leading-edge technology to develop high value biological materials from packing plant by-products. Another project uses biotechnology to produce new strains of lactic acid bacteria for extending meat storage life. These bacteria are similar to those used in the manufacture of cultured dairy products such as cheese and yogurt.

A beef research project for the investigation of *in vitro* bovine fertilization and embryo production was a prime example of the high technology and diversification required for Alberta to compete globally. Preliminary findings indicate potential for Alberta to be a leader in the commercialization of frozen bovine embryos. Other examples of biotechnology research with commercial application in animal agriculture include:

- a) genetic probing for sexing of embryos; determination of protein types
- b) gene mapping and the endless possibilities that go on in this *in vitro* experimentation
- c) embryo splitting to produce genetically identical calves
- d) using protein from fish blood to protect frozen embryos and semen to increase survival rates
- e) development for improving meat quality (low fat, low salt, low cholesterol)
- f) development of meat for specific markets (Japanese prefer marbled beef)

Alberta is clearly a leader in animal agriculture. One of our companies, Alta Genetics Inc. is developing and selling products to over 50 countries. They have formed alliances with other country's universities and provide training and expertise to them. They operate two wholly-owned U.S. subsidiaries and have offices in three Latin American countries and representatives in many other international centres.

Plant Agriculture

Although there are now global surpluses in some agricultural foods such as wheat, we cannot expect them to last. In an article in the September 1994 issue of *New Scientists*, *Debra Mackenzie* examined the precarious relationship between food production and

population growth. Biotechnology is pinpointed as one of the few hopes we have to increase food production.

Cereal crops have anchored the province's agricultural industry since its pioneering days. Alberta is a major producer of wheat and canola and is the leading producer of barley in Canada. These crops generate substantial revenues but are subject to world commodity pricing. Biotechnology can be used to improve production of existing crops or develop alternative crops for production of novel products.

By introducing alternative genes, compounds and products can be produced that are not normally associated with plants. A **Calgary researcher** is working with genetically-engineered canola to produce a protein that stimulates the immune system. Within our Province, further value can be added by processing, extraction and purification of these proteins.

Alberta is in a position to benefit from our present and developing expertise in plant agriculture. The benefit comes in three forms: 1) increased profitability through improved quality, increased yield and/or reduced costs, 2) development of alternative crops for production of novel products, and 3) revenues from export of our crops, products, and technology.

Farmers in Alberta realize that one step to economic stability is diversification. The February 1995 Federal Budget may have farmers looking at crop alternatives to reduce costly transportation charges. Vegetables, potatoes and sugar beets not only provide diversification options to producers, they also contribute to soil fertility and soil/water conservation. Fermentation technology can use cereal starches for production of value-added products (e.g. organic acids, biopolymers, vitamins, and natural flavors).

Farmers will likely choose a crop with a resistance to disease, high yield and ready market. An example of an alternative with excellent market potential is the potato. There is an active Western Canada potato breeding program to maintain genetic and environmental advantages for Alberta potatoes. By combining biotechnology with traditional plant breeding, researchers are solving the potato industry's challenges of preventing crop losses from insects and disease, and improving processing characteristics. The Potato Growers of Alberta estimate that value-added to fresh, seed and processed potatoes by our 15 packing and processing companies generate up to \$340M in provincial economic activity, much of that through exports to the Pacific Rim, Mexico and the U.S.

The quality of life advances made possible by genetically enhanced food materials through maintaining or improving health, is positive for Canada and the world.

Aquaculture

With the depleting fishstocks, aquaculture can provide an alternative source for this needed source of protein. Alberta farmers are seeking diverse forms of agriculture to stabilize their long-term incomes and trout production from farm ponds and dugouts is a way of income diversification. In 1991, the Alberta Agricultural Research Institute estimates there were 2300 private fish farms in Alberta. Water quality is a critical factor in pond production and biological water treatment improves water quality needed for high yield.

Epicore Networks Inc. has established a global presence in marketing their technologies and services for the treatment of waste, soil and water to various industry sectors, including aquaculture. Headquartered in Calgary, Epicore Networks Inc. has associated companies in Indonesia and the United Kingdom and a technology centre in New Jersey, U.S.A.

Environmental Applications

Soil and Water Remediation

An important environmental application of biotechnology is bioremediation. This involves the harnessing of naturally occurring microorganisms that feed on chemical compounds, breaking them down into non-toxic substances. These microbes, known to have existed for millions of years, are capable of removing sludge and heavy metals from liquid streams. They are now being used to degrade pollutants and previous non-biodegradable contaminants found in industrial and municipal waste. The ability of these microbes to degrade such materials is being enhanced through the use of biotechnology.

Opinion polls indicate that the general public is concerned about global environmental protection. Accordingly, governments around the world have placed environmental concerns high among their priorities.

Kiseki Environmental Corporation (1992 sales revenue \$4M), based in Calgary, has developed a biotreatment system to provide industry with a cost effective method of cleaning up oilfield and industrial wastes. They have major distributors for their products in the U.S., Brazil and Mexico.

Cleaning and Sanitation

Environmental concerns have led to the development of many biodegradable cleaning products for institutional and commercial use. Examples include products for drain and grease trap cleaning, rug and upholstery shampoo, and septic and recreational vehicle tank cleaning.

Waste Disposal

Waste disposal is a growing problem, especially in heavily populated countries and the agricultural industry. Inadequate disposal contaminates ground water and creates intolerable odors. Products using microorganisms have been developed and produced by Alberta companies, many being marketed to other countries.

Forestry

The industry works in an integrated fashion to provide a healthy balance between research, industry and environmental needs. Provincial representatives, industry (saw mills, pulp and paper mills, seed banks), and university faculty and students meet regularly for open discussion. Research and product development occur at both the university and industry level. The application of biotechnology to this industry occurs at the planting stage as well as the pulp and paper mill.

Plant Development

The province has suitable policies in place to commit companies to reforest cut down areas, but no incentive is provided to select seedlings with stronger growth or disease resistance. Reforestation requires a 60 to 120 year investment and efforts must be made to continue thinking in terms of generations and not annual financial statements.

Genetically enhanced seedlings are being developed by Alberta researchers to increase disease and pest resistance. Research is also conducted to increase the rate at which a seedling will flower. Micro-organisms introduced into soil to promote rapid growth and root development of seedlings can be produced locally. This could take years off the growth life cycle of a tree. Benefits derived from such enhanced trees may not be seen in our lifetime, but certainly in our children's.

Pulp and Paper

Environmental issues relating to pulp and paper by-products have received considerable media attention. This area of forestry has therefore received a greater share of attention and great strides have been taken to develop products and processes to reduce harmful by-products. Biotechnology has resulted in the implementation of enzymes to reduce dioxin and organic chlorine emissions from pulp and paper bleach plants. They can also be used to partially bleach wood pulp, thereby reducing the need for chlorine in paper production.

Mining

Applications of biotechnology in the mining industry are not as widespread as in other industries. Over the past several years, industry, research organizations, government laboratories, and universities in a large number of countries have participated in the

exploration of the possibilities of biotechnology application in the mining industry. Today, several technologies are used commercially in well understood and engineered systems. Many more technologies have been demonstrated at the laboratory or pilot plant scale. Although initial developments were aimed at metal extraction applications, the dramatic increase in environmental awareness and the practice of sound environmental management demanded by increasingly stringent regulations over the past decade has led to serious investigation of biotechnology for environmental control.

The Canadian mining industry will have to develop and adopt new technologies to remain competitive in the future. Governments are under pressure to minimize the environmental impact of mining processes on public safety. Companies positioned to adapt to these changes through the use of innovative technologies will have a strategic advantage.

Fossil Fuels

Desulfurization of fossil fuels (coal, oil, oil shales, flue gas) offers a vast potential market for biotechnology. Many biotechnological applications exist specific to the oil sector. A few examples include the microbial degradation of refinery sludges and slop oil; microbially-enhanced oil recovery and site remediation to degrade petroleum products. With application to both upstream and downstream operations, the optimization potential will certainly be realized as benefits to many companies in our province.

ISSUES SPECIFIC TO THE ALBERTA BIOTECHNOLOGY INDUSTRY

Infrastructure for Scientific Research

Alberta has an excellent infrastructure for the development of biotechnology supported by substantial public funding. There is great opportunity for people within the science community to integrate their research efforts. This team approach, combining intellectual efforts and research capabilities, has been demonstrated by a number of our facilities and efforts must be made for continued benefit from these synergies.

The **Alberta Heritage Foundation for Medical Research (AHFMR)**, together with the University of Calgary and the University of Alberta, has recruited more than 150 senior scientists from Canada and around the world. These medical researchers now attract support from industry and other public funding agencies at a rate of two to three dollars for every dollar invested by the AHFMR. Since 1980, AHFMR has contributed more than \$450M directly to the scientific community in Alberta. External funding of over \$1B has been the result of this Foundation investment (AHFMR 1994 Annual Report).

In 1993, the second International Board of Review declared the Alberta Heritage Foundation for Medical Research has made Alberta one of the top ten medical centres in North America.

The **University of Alberta** has established an Advisory Committee on Biotechnology to enhance biotechnology research in Immunology, Forestry, Pharmacy, Pediatrics, Zoology, Chemical Engineering, Biochemistry, Soil Science, Microbiology and Genetics. There is also a Biotechnology Centre in Agriculture, Food and Nutritional Science.

The **University of Calgary** focuses its strengths on biomedical research and plant biology, as well as in the areas of engineering, animal health and energy sector biotechnology. The University recently established a research chair in plant biotechnology, jointly with NSERC and DowElanco Canada. This now involves a team of 25 researchers, with two thirds of the overall funding coming from the private sector.

The **University of Lethbridge** biotechnology research focuses on molecular and biochemical studies of agricultural crops. Their DNA-based procedures in the study of plant science is possible because of qualified plant scientists as well as well-equipped laboratories.

In 1984, the **Alberta Research Council** in Edmonton established a **Biotechnology Pilot Plant**. It offers a crucial *scale-up* in its fermentation facility and conducts research through its Biotechnology Department. The **Biotechnology Department** also assists in the agriculture, environment and forestry sectors. The Alberta Research Council provides services on a contract research basis or through Joint Research Ventures. Through this development process, new corporate entities can be established.

Other facilities offering research and development programs to the biotechnology industry include, **The Institute of Pharmaco-Economics**, **The Alberta Agricultural Research Institute**, **The Alberta Environmental Centre** (Vegreville) and the **Agriculture and Agri-Food Canada** research station (Lethbridge and Lacombe).

The ripple effect created by combining expertise from these facilities has been demonstrated and works to our advantage. The presence of highly qualified scientists attracts other researchers which in turn attracts more funding. This strong scientific base is required to attract large, international companies in knowledge intensive industries to our province.

To maintain excellence, investment to improve and update our facilities must continue. With budgetary constraints, the challenge to maintain such excellence exists. Any significant decrease in the quality of infrastructure will lead to a reduced ability to attract and retain researchers and a corresponding reduction in investment by private industry.

Human Resources

Alberta has an excellent education system and sound mechanisms for training. Biotechnology will create new jobs in the life sciences, engineering, management, manufacturing and bioprocessing, marketing and related support industries. The needs of the industry will change as it continues to grow, and we must anticipate the human resource needs such that they can be met by Albertans.

Scientific Personnel

The excellence of our scientific and research community has been recognized internationally. We provide an excellent environment to develop the expertise and skills of our young, budding researchers. While we attract researchers from around the world, steps must be taken to assure continued support and stability for our researchers during times of economic uncertainty. Some of these researchers will return to their home country, but many times relationships developed in Alberta lead to collaborative research and industry trade in future years.

Qualified technicians trained in production and bioprocessing are not in abundant supply. The Alberta Research Council facility in Edmonton does not have a shortage today, but indicates that qualified individuals were difficult to locate and have concerns for the future.

Management

Many of the biotechnology companies in Alberta identified the importance of management to the success of their firms. Technology based firms require managers capable of providing a range of skills, especially finance, marketing and production expertise. Such managers are in short supply and experience has shown that management skills are often not successfully transferred between industries.

Some countries have biotechnology companies at more mature stages of product and market development. Attracting expertise from these companies is one way of meeting the management needs of emerging Alberta biotechnology companies. It is essential that immigration policies not hinder the recruitment of skilled and experienced managers.

Establishing a *cluster* of experts in academe and business, could lead to rapid growth of the biotechnology industry in Alberta. This would lead to a model similar to Silicon Valley in California or Route 128 in Boston.

Issues of Technology Transfer

Research and Development

In Alberta, much of the research in biotechnology is publicly funded. The investment is substantial, yet the economic benefit back to the province is minimal. These institutions do outstanding work, yet the mechanisms for transferring research into economic benefit, including jobs, are not well developed. Sometimes the science developed within our province is *sold* and commercially exploited elsewhere. Although an immediate cash settlement or minor royalty payment occurs, this should by no means be considered a successful outcome. Recognition as a science and technology leader, along with job creation and economic growth should be the desired goal.

Lack of Incentive for Researchers

Researchers in academe and government laboratories often lack incentives to do more applied research. Recognition in the scientific community is often what motivates these individuals. When a commercial application is identified, the researcher may not want to spend time away from his/her laboratory in meetings and in preparing necessary documents.

Research is generally not directed toward commercial activities, yet this is becoming a necessity because of the reduction of public funds allocated for this purpose. There is a need for balance between basic science and applied research to generate the knowledge needed for application to biotechnology.

Few firms have been spun off from university research and only a few academics have been involved in start-up companies. In many cases, it is the researcher alone that understands the technology and he/she is required to champion the product throughout its market life.

Technology Transfer and Diffusion to Industry

Inadequate financial support at this stage of development is typical. Preliminary stages of research and development also require steps be taken for protection of intellectual property. The **technology transfer offices** at our universities are often called upon for help in this area. However, legal fees at this early stage can be costly and budgets at these offices limit the number of patents that can be filed each year.

Since access to adequate funding is difficult, many of the early-stage technologies require an industry partner willing to invest in a long-term project. The risky stages of development require that near-term investment be made to create greater long-term benefits. Investors are typically driven to optimize short-term behavior, which accentuates the funding gap problem.

A number of opportunities presented to technology transfer services cannot readily be matched with industry partners. The human and financial resources do not permit adequate identification of each opportunity, resulting in many technologies remaining “on the shelf”. **Links** between **industry** (both local and international), **government research facilities** and **university researchers** are surprisingly **weak** and opportunities lost as a result. There is limited coordination of efforts between the two **technology transfer offices**. The geographic dispersion of our research centres leads to further breakdown of our networking structure.

Accessing Capital

At all levels of product research and development, obtaining adequate financing is a challenge. By making funds available to start-up firms, companies will be encouraged to stay in Alberta. By employing more aggressive financial mechanisms to attract investment, other provinces and countries will surpass Alberta in its attempt to establish, attract and retain industry in the province.

Raising capital is difficult for biotechnology companies because of the large investment needed to develop a product and the length of time it takes to meet licensing requirements. In Alberta, we have many technologies at very early stages of development. The two technology transfer offices have far more proposals than can be processed. We have many more companies requiring funding for developing prototypes, marketing business strategies, and intellectual property protection. A number of companies require funding to support later stages of commercialization including final product development, market surveys, business organization, and clinical trials. Investing in these companies is essential to secure the sector’s future.

Most research in Alberta is funded by government grants and the AHFMR. Small firms generally start out with **private financing**, often from family and friends, or on occasion, an industry partner. **Banks** traditionally favor low risk investment and have not been a ready source of capital for biotechnology start-up companies. The **venture capital industry** in Canada has shifted its attention away from early-stage high technology deals, to less risky later-stage financing. Other provinces have established **Labor Pension Funds** as a vehicle for investment in research and development.

Further along the development path, **industry partners** often help with growing and diverse needs. Raising larger amounts of capital on **equity markets** is costly and generally geared to larger firms. In 1994, there were 48 companies listed as biotechnology stocks on the stock exchanges in Canada, four of those on the **Alberta Stock Exchange**. Equity markets have historically not targeted research or knowledge based firms. Lack of investor knowledge and confidence in this industry makes equity markets a challenging source of capital.

Accessing capital is a major impediment to growth of industrial biotechnology.

Public Awareness

Broader consumer acceptance of biotechnology-enhanced products and processes is required to build a positive environment for Canadian biotechnology industries. A national study to provide a benchmark to gauge public awareness and attitudes on biotechnology was completed in **November 1994**. The study involved preliminary focus group sessions; a national telephone survey of 2000 adult Canadian, and post-survey focus groups to further increase the understanding of the survey data.

Highlights of the study:

- Generally, respondents were comparatively unfamiliar with the subject of biotechnology. They assessed different issues and applications individually, according to perceived benefits. They have not yet reconciled how developments in biotechnology fit into their value systems. Respondents generally expressed cautious optimism regarding the potential benefits of biotechnology, yet they may not necessarily accept all biotech products. While they recognized possible benefit to society, they were wary because of previous mishaps (e.g. thalidomide, silicone breast implants).
- Even though respondents indicated a preference for a no-risk policy, expressing a desire to have control, tolerance varied from case to case. They were more likely to accept greater risk in pursuit of health benefits (e.g. cure for diseases). Almost all respondents expressed a desire for labeling of biotech products to enable them to make choices. Most respondents looked to government to play several proactive roles in the field of biotechnology - investigating and ensuring the safety of biotech products, as well as in consulting the public on regulations and ensuring that clear and balanced information about biotech products and processes is available to the public.
- There was a consensus that government should regulate biotechnology with a view to public safety. Respondents felt that government should be responsible for ensuring that new products hold minimum health and safety risks for individuals, society and to the environment.

The media are beginning to recognize the impact that biotechnology may have on our lives. A March 6, 1995 article in Maclean's magazine entitled "*Changing the face of the farm*" focused on this issue. Many Alberta companies, especially those in agriculture, are acutely aware of the importance of keeping the consumer informed. In fact, an Alberta Agricultural Awareness specialist has recently founded the Western Canadian Agricultural Education Council aimed at agrifood biotechnology awareness.

Some applications of biotechnology raise important social and ethical questions, and there is a broad spectrum of views on the issues. We must be certain that the market is well-informed and educated on the benefits biotech products can provide. Providing the public with a clear understanding of biotechnology through a **science-educated media** is crucial.

Regulations

Regulations have a great impact on the biotechnology industry. The U.S. has taken steps to provide a reasonable regulatory environment and continues to maintain its dominance in the field of biotechnology. It remains cognizant of the ethical issues in doing so. The European Union has embarked on a biotechnology regulatory approach aimed at regulating process rather than product.

Consideration must be given to the impact of federal, provincial and municipal regulations. To retain and attract biotechnology companies, Alberta and its municipalities must coordinate their efforts to provide a **reasonable regulatory environment**. Much of the time and money spent to comply with the regulatory process occurs at the Federal level. Attempts must be made by all three levels of government for a collaborative approach to providing a reasonable and competitive regulatory environment. This would include attempting to reduce the time required to process such documents. A backlog of submissions hinder small companies with only one or two products when they must wait inordinately long periods for product reviews.

Some Alberta companies have decided not to carry out certain clinical trials in Canada. While there are many reasons for this, a reasonable regulatory environment would help support the biotechnology industry.

Intellectual Property Protection

Protection of intellectual property is a necessary part of all stages of product development. Albertans involved in the biotechnology industry understand the detail and time required to complete documentation. The technology is in the head of the researcher and the time taken to complete this task means time away from research. Unfortunately, long periods of time are required to process the documentation, indicating a shortage of qualified individuals to handle the volume.

The cost in filing varies with the complexity of the technology, but many times it is a limiting factor in start-up ventures or at the university technology transfer level. More complex technologies often leave the researcher with no alternative but to seek legal assistance from experts in biotechnology. Many of our companies process their applications through U.S. law firms, either to obtain U.S. patent protection or because Alberta and Canada cannot provide the expertise required for this new industry. This adds further expense, but the accuracy can be a vital component to the protected success of the marketable product.

The cost and time required for intellectual property protection is significant. An Alberta biopharmaceutical company established to research, develop and commercialize new drugs for neuron replacement or repair, employs a full-time individual to co-ordinate patent application processes. This is in addition to the \$15,000 per month in U.S. patent attorney fees.

Partnering

Developers of technologies can benefit by developing a synergistic relationship with a partner. The benefits derived from such a relationship include financial and human resource expertise, networking, production capability and distribution channels. Companies ally for a variety of reasons: to create synergy with similar technologies, to consolidate interests, to gain access to markets (both domestic and foreign), to access capital and personnel, or to reduce redundancy. Interprovincial partnering can provide similar benefits, as would combined research efforts between government and university research.

One assumption affecting Alberta into the 21st century is that growth in world trade will be related to knowledge-intensive and high technology products. This global orientation will require many of our biotechnology companies to seek alliances in other countries. Much of our international trade already occurs with Europe, Japan and Asian countries. Our expertise and their market potential should provide much opportunity for our industry.

SemBioSys Genetics Inc., a new Calgary-based agbiotech firm, is planting 1 ton of genetically-altered canola seed this year. The protein extraction process will occur in a Saskatchewan facility keeping capital cost of equipment to a minimum. If this procedure proves successful, processing and product refinement facilities could be built in Alberta. This partnering benefits both provinces.

Strong Voice for Industry Alberta has recognized the importance of biotechnology for growth and long-term economic development. We also have the infrastructure and expertise to become an internationally recognized centre for biotechnology.

The importance of an informed public for market acceptance of products from the biotechnology industry has been clearly identified. The federally funded study published in 1994 and the increasing media interest in this industry indicates the urgency in raising the profile of biotechnology.

Biotechnology is fragmented not only by industry, but by geographic location. This lack of concentrated effort is confusing to the consumer and to the investment community. A unified effort to build an industry policy within the province will provide the strength to remain competitive.

VISION FOR THE FUTURE

The Opportunities

Jobs

Biotechnology is acknowledged to be one of the high growth industries of the new knowledge-based economy with enormous potential as a pervasive enabling technology. In the U.S., the biotechnology industry is a significant generator of jobs, employing 97,000 people in 1993 at 1270 core biotechnology firms. In the same year, Canada's 120 core biotechnology firms employed 6500 people², an average annual increase of 14 percent between 1989 and 1993. Many Alberta companies are now approaching the critical stage of commercialization. With proper government encouragement and a positive investment climate, these companies could soon grow to become an important source of jobs and revenue.

Biomira Inc., a company dedicated to the diagnosis and treatment of cancer, was formed in 1985 through the efforts of two University of Alberta researchers. Located in Edmonton, Alberta, Biomira Inc. was one of the first biopharmaceutical companies listed on the Toronto Stock Exchange. Today, it directly employs over 150 people in Alberta.

Economic Growth

There are few sectors that can rival biotechnology in their potential for economic growth. An estimated \$15 billion worth of biotechnology products were sold worldwide in 1993. It is estimated that total sales will grow rapidly over the next few years to reach \$75 billion to \$150 billion by the year 2000. In Canada total sales from biotechnology products were \$2 billion in 1993, with sales growing at an average annual rate of 24 percent from 1989 to 1993.

Export Potential

Forty percent of Canada's sales in the biotechnology industry are due to exports. The \$750 million of biotechnology product exports in 1993 represents an average annual increase of 19 percent from 1989. Exports are an important source of new economic activity and every \$1 billion in exports creates 15,000 jobs. Biotechnology products and processes made in Alberta have an attractive export potential.

Alberta's total exports in 1994 reached \$23 billion, up 16 percent from \$19.7 billion in 1993. Exports by the province's agri-food sector jumped 28 percent from 1993 to \$3.6 billion. Exports of value-added products (where commodities are processed in Alberta creating local jobs rather than exported in a raw state) increased 24 percent to \$1.3 billion.

² Canada's Export Strategy, The International Trade Business Plan 1995/96

In April 1995, an Alberta biotechnology company signed a trade deal with South America. Alta Genetics has agreed to a \$1.2 million deal that will send 1000 cattle embryos to a consortium of Brazilian breeders. Less than one month prior to this, Alta Genetics exported 300 cattle to China.

APPENDIX 1

Members of the Biotechnology Committee:

Chairman

Dr. W.A. Cochrane, President, W.A. Cochrane & Associates Inc.

Alberta Science and Research Authority Board Members

Dr. R. Collins-Nakai, Associate Dean - Faculty of Medicine, Professor of Pediatrics, University of Alberta

Dr. R. Rennie, New Products R&D, Cominco Fertilizers Ltd.

Mr. I. Hamilton, Senior Manager, Innovation and Technology, Bank of Montreal

Support Staff

Dr. A. Sailer, Masters Program, Faculty of Management, University of Calgary

April 19, 1995 Focus Group Meeting:

The Chairman and all members of the Biotechnology Committee

Dr. A. Sailer

April 27, 1995 Focus Group Meeting:

Dr. W.A. Cochrane, Committee Chair

Dr. R. Church, Chairman, Board of Management, ASRA

Mr. Ken Broadfoot, CV Technologies

Mr. Scott Cormack, NeuroSpheres Ltd.

Dr. Ian Forrester, Gemini Biochemical Research Ltd.

Mr. Ian Hamilton, Bank of Montreal

Ms. K. Jeramaz-Larson, Royal Bank of Canada

Dr. James Murray, Intellectual Property, University of Alberta

Ms. Barbara Nyland, Director, ASRA

Dr. A. Sailer

Mr. Daniel St. Gelais, Epicore Networks Inc.

Dr. Yilma Teklemariam, Alberta Agriculture, Food and Rural Development

Dr. Brad Thompson, Synsorb Biotech Inc.

APPENDIX II

Interviews Conducted by the Committee:

Institutions, Companies and Individuals Visited:

1. Dr. James Murray, Director Industry Liaison Office, University of Alberta
2. Mr. J.M. Curtis, Business Development and Chemical Production, Alberta Research Council
3. Dr. A. McPherson, President and CEO, Biomira Inc.
4. Dr. B. Dancik, Professor and Chair, Department of Renewable Resource, University of Alberta
5. Mr. M. Hamilton, Director Medical and Biological Sciences, Technology Development Branch, Economic Development and Tourism
6. Dr. M.W. Spence, President, Alberta Heritage Foundation for Medical Research
7. Mr. D.J. Rafter, Vice President Product Development, Synsorb Biotech Inc.
8. Dr. T. Mitenko, Vice President, Alta Genetics Inc.
9. Ms. B. Sheridan, President and CEO, University Technologies International Inc.
10. Mr. A. Stuart, Manager, Potato Growers of Alberta
11. Dr. M. Moloney, Department of Biological Sciences, University of Calgary
12. Mr. I.K. Hamilton, Senior Manager Innovation and Technology Centre, Bank of Montreal
13. Dr. R.J. Fessenden, Vice President, Alberta Research Council
14. Dr. W.T. Leps, Section Head Biology Research and Production, Alberta Research Council
15. Dr. R. Christian, Executive Director, Alberta Agricultural Research Institute
16. Dr. G. Lewis, Environmental/Biotechnology Consultant
17. Dr. K. Adachi, Industry Liaison Office, University of Alberta
18. Dr. L. Behie, Faculty of Engineering, University of Calgary
19. Dr. I. Fortune, Executive Vice President, Epicore Networks Inc.
20. Dr. R. Collins-Nakai, Associate Dean, Faculty of Medicine, University of Alberta

Special Thank you to:

Dr. M. McLaughlin, Ag-West Biotech
Dr. R. Church, Chairman, Alberta Science and Research Authority
Barbara Nyland, Director, Alberta Science and Research Authority
Ms. Carol Cheffins, Director, Biotechnology Directorate; Industry Canada
Mr. Graham Strachan, President & CEO, Allelix Biopharmaceuticals

REFERENCES

1. **National Biotechnology Business Strategy: Capturing Competitive Advantage for Canada**
National Biotechnology Advisory Committee; Fifth Report 1991
2. **The Role of Biotechnology in the Canadian Mining Industry - Phase 1**
Prepared for Industry, Science and Technology Canada
R. W. Lawrence, R. Poulin, G.W. Poling
Department of Mining and Mineral Process Engineering
University of British Columbia
Vancouver, B.C.
3. **The AgBiotech Bulletin**
Volume 3, Issue 1, January, 1995
Published by Ag-West Biotech Inc.
4. **Alberta Agriculture Research Institute**
Annual Report 1991 - 1992
5. **Alberta Heritage Foundation for Medical Research**
1993-94 Annual Report
6. **Federal Expenditures for Biotechnology 1989-1992**
Biotechnology Directorate
Chemicals and Bio-Industries Branch
Industry, Science and Technology Canada
March 1993
7. **Understanding the Consumer Interest in the New Biotechnology Industry:**
A Market Study (Optima Consultants)
November 1994
8. **Canadian Biotechnology**
1994/5 Company Directory
By Fred Haynes, Phd.
Contact International Inc., May 1994
9. **Biotech 90: Into the Next Decade**
Fourth Annual Survey of Business and Financial Issues in America's Most Promising Industry
G.S. Burrill (Ernst and Young High Technology Group)
Published by Mary Ann Liebert, Inc.

10. **Biotech '92: Promise to Reality**
An Industry Annual Report
G.S. Burrill, K.B. Lee Jr. (Ernst and Young)
11. **Canadian Biotech /92 Towards Realization**
Business and Financial Survey of the Canadian Biotechnology Industry
T. Going, P. Winter (Ernst and Young)
12. **Biotech 93, Accelerating Commercialization**
Seventh Annual Report on the Biotech Industry
G.S. Burrill, K.B. Lee Jr. (Ernst and Young)
13. **Biotech 94, Long-Term Value - Short Term Hurdles**
Eighth Annual Report on the Biotechnology Industry
G.S. Burrill, K.B. Lee, Jr. (Ernst and Young)
14. **Biotech 95, Reform, Restructure, Renewal**
Ninth Annual Report on the Biotechnology Industry
G.S. Burrill, K.B. Lee Jr. (Ernst and Young)
15. **Canadian Biotechnology 1993**
Company Directory
Frederick J. Haynes Ph.D.
Contact International Inc.
16. **Biotechnology Public Awareness Workshop**
Summary of Proceedings
Industry, Science and Technology Canada
February 11-12, 1993
Ottawa, Ontario
17. **Making Technology Happen: A Handbook**
D.J. Doyle, Doyletech Corporation.
Kanata, Ontario 1990
18. **Biotechnology: A Strategic Plan for Ontario**
A Report from the Biotechnology Council of Ontario
September 1994.
19. **Canada's Export Strategy: The International Trade Business Plan 1995/96**
Sector 5: Biotechnologies
Industry Canada, Biotechnology Directorate